

CLAIMS

1. A method of determining the relative amounts of different chemical elements E1 to En in the chemical composition of a crystalline semiconductor material, the method comprising diffracting a beam of radiation off the crystalline material and measuring the angle of at least one diffraction peak and the intensity of a portion of the diffracted radiation integrated over a portion of the at least one diffraction peak located at said diffraction angle, and using a processor to determine the relative amounts of the elements E1 to En in the chemical composition of the crystalline material by using values derived from the radiation scattering powers of the elements E1 to En and the position and integrated intensity of said portion of said at least one diffraction peak.
2. A method according to claim 1 in which the or each or some of the diffraction peaks, or the or each or some of the portions of the diffracted energy, is at a quasi-forbidden angle of diffraction from the semiconductor material.
3. A method according to claim 1 in which the or each or some of the quasi-forbidden diffraction is at a (002) reflection.
4. A method according to claim 1 or claim 2 in which the or each or some of the quasi-forbidden diffractions is at a (006) reflection.
5. A method according to claim 1 in which the or each or some of the diffraction peaks or the or each or some of the portions of the diffracted energy is resultant from a (004) reflection.

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6. A method according to any preceding claim which comprises using a knowledge of the structure of the material and the possible elements present in the material to determine the chemical composition of the material.

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7. A method according to claim 1 or any claim dependent directly or indirectly from claim 1 in which the crystalline semiconductor material is assumed to be comprised of only a finite number of known predetermined chemical elements and the processor has operational in its processing of the measured input data and stored element scattering power values only the scattering powers for the known predetermined assumed finite number of elements that are assumed to be present.

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8. A method according to claim 7 in which the material is assumed to be comprised of four or less chemical elements.

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9. A method according to any preceding claim which comprises determining the composition of a layer of a material and makes use of a knowledge of the thickness of the layer, or an assumption of the thickness of the layer being analysed.

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10. A method according to any of claims 1 to 9 which comprises determining the composition of a single layer of a material on a substrate of the material.

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11. A method according to any preceding claim which comprises measuring the position of at least two diffraction peaks or at least two portions of the diffracted energy and using a knowledge of their position to determine the relative amount of chemical elements in the chemical composition of the semiconductor material.

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12. A method according to any preceding claim which comprises measuring the intensity of diffracted beams at at least two positions or measuring the intensity of at least two portions of the diffracted energy and using this knowledge to determine the chemical composition of the semiconductor material.

13. A method according to any preceding claim which comprises measuring the intensity of two diffraction peaks or two portions of the diffracted energy.

14. A method according to any preceding claim in which the semiconductor material is a quaternary semiconductor material.

15. A method according to any one of claims 1 to 13 in which the semiconductor material is a ternary semiconductor material.

16. A method according to claim 14 which further comprises measuring or assuming a parameter indicative of the lattice parameter of the quaternary semiconductor material, and using this parameter and the intensity of a diffraction peak or the parameter indicative of the intensity to provide, in a single diffraction measurement, an estimate of the composition of the material.

17. A method according to any preceding claim in which the semiconductor material is a III-V semiconductor material.

18. A method according to any preceding claim in which the composition of an at least partially strained semiconductor material is analysed.

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19. A method according to any preceding claim in which the semiconductor material is a single crystal material.
20. A method according to any preceding claim in which the percent of each chemical element of the chemical composition of the semiconductor material is analysed with an error of 0.1% or below.
21. A method according to any preceding claim which further comprises measuring a parameter indicative of the lattice parameter of the semiconductor material.
22. A method according to claim 21 which is used to analyse the composition of a buried, non-surface, layer in the semiconductor material.
23. A method according to any preceding claim which further comprises comparing the detected composition of the semiconductor material to a reference composition to determine if the detected composition is equal to that composition or falls within a predetermined range around the reference composition, and producing a first output if the measured composition falls within the range and a second output if the measured composition falls outside the range.
24. A method of analysing the composition of an at least partially strained material comprising irradiating the material with energy from an energy source which energy is diffracted from the material, detecting one or more portions of the diffracted energy, and analysing the or each detected portion to obtain a parameter indicative of the position and/or intensity of the or each portion.

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25. Chemical composition analysis apparatus comprising a sample holder, a beam source, a detector or detectors, a controller, and a processor, the controller being adapted to control the beam source and detector in use so as to direct a beam of energy onto a sample held in the sample holder and detect diffracted energy at diffraction angles, the detector(s) being coupled to the processor to provide the processor in use with signals representative of the position of a diffraction peak and the intensity of the diffraction peak, and the processor being arranged such that in use it uses the detected signals, in combination with an assumption of what predetermined elements are present in the sample and the scattering power of atoms of the elements that are assumed to be present, or a factor dependent upon the scattering power of the predetermined elements, to evaluate the relative amounts of the predetermined chemical elements in the chemical composition of the sample.

26. Apparatus according to claim 25 having an element selection inputter adapted to enable a user to identify to the processor which chemical elements are to be assumed to be present in the sample to be analysed, and therefore which chemical element scattering powers, or factor dependent upon the scattering powers, are to be used by the processor in determining the relative amounts of the chemical elements in the sample, the processor being adapted in use to operate with its processor on the measured input variables from the detector(s) and a subset of element scattering powers, or derived values, selected from a larger set of stored element scattering powers, or derived values, the subset being selectable by the operation of the element selection inputter.

27. Apparatus according to claim 26 or claim 27 in which the sample holder, beam source and detector(s) are pre-set at predetermined positions relative to each other at a relationship where for a sample of a known kind

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the or at least one detector is disposed so as to detect at a quasi-forbidden diffraction angle.

28. Semiconductor wafer checking apparatus comprising apparatus
5 according to any one of claims 25 to 27.

29. A data carrier carrying a programme which when running on
detection apparatus is adapted to enable the apparatus to perform a method
of any one of Claims 1 to 24, or which when loaded into a control
10 computer of the detection apparatus is adapted to provide the apparatus of
any one of Claims 25 to 28.

30. Apparatus for the analysis of the composition of a semiconductor
material being arranged to operate in use in accordance with the method
15 of any of claims 1 to 24.

31. A composition measurement system arranged to analyse the
composition of a semiconductor material according Claim 1 and to
compare this to a reference or output the results of the analysis.

20 32. A method of manufacturing a semiconductor chip comprising
manufacturing a semiconductor wafer, analysing the composition of the
wafer according to any one of claims 1 to 24 to test if it passes or fails a
composition analysis test, and performing fabrication operations on the
25 wafer to produce the chip if the wafer has a composition within
predetermined parameters, and rejecting the wafer for further processing
or fabrication operations if it has a composition outside of the
predetermined parameters, rejected wafers not being subject to at least
one processing step that they would have received had they passed.

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33. A method according to claim 32 in which wafers that pass the compositional analysis test and/or chips produced from such wafers are accompanied by data either confirming that they passed, or data giving details of their compositional analysis.

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34. A method of determining the relative amounts of different chemical elements in the chemical composition of a crystalline quaternary semiconductor material, the method comprising diffracting a beam of radiation off the crystalline material and measuring the angle of at least one diffraction peak and the intensity of diffracted radiation at that diffraction angle, and using a processor to determine the relative amounts of the elements in the chemical composition of the crystalline material by using values derived from the radiation scattering powers of the elements and the position and intensity of said at least one diffraction peak.

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